Technological innovations

Stephen Intille, Ph.D.
Technology Director
Changing Places / House_n Consortium
Massachusetts Institute of Technology

September 6, 2003

Take away: 4 new opportunities

- Continuous, rich recording from a variety of sensors
- Algorithms to process data to reduce coding time
- *Context-sensitive* data collection to collect data and prompt for self-report at desired times and places
- *Context-sensitive*, personalized interventions

Your task…

What are the possibilities for *your* research?

Relevance to health research (1)

- Ability to better study how context (people, places, things) impacts behavior
- Examples
  - Measurement of moderate intensity or greater physical activity
  - Dietary decision making
  - Making every interruption count

Relevance to health research (2)

- Ability to create and measure impact of "just-in-time" interventions
- Example: physical activity
  - Measurement is important, but we already know people don't get enough physical activity!
  - Just-in-time detection of activity for positive reinforcement

Overview

- New developments
- Examples
  - Context-sensitive experience sampling
  - Portable kit of "tape on" environmental sensors
  - PlaceLab
- Emerging opportunities
- Challenges

New developments

- **New developments**
- Examples
- Emerging opportunities
- Challenges

Data collection in the (not-so-distant) future

- Record and save everything from subjects:
  - 24/7 video stream (160x120 resolution,10fps,MPEG-4) [1.56 GB/day]
  - 24/7 audio stream (24kHz mp3) [.57 GB/day]
  - 24/7 1 photo per minute or other data [.57 GB/day]
  - 16/7 One 3MB data file per hour [72MB/day]

- A year of data: **990MB**
- 2007: Terabyte of data <$300

Sensors in the (not-so-distant) future

- Example:
  - Video/photos from miniature pocket/cap camera
  - Continuous audio recording, keyword detection
  - Real-time HR data
  - Real-time motion data all limbs, hip
  - Real-time indoor/outdoor position
  - Real-time position relative to other people
  - Real-time data from home: objects touched/used
  - Data on use of communication devices
  - No encumbering or nerdy-looking devices
  - Context-sensitive self report

Data analysis in the (not-so-distant) future

- Computers pre-process data:
  - Translate noisy sensor data into meaningful labels E.G. Cooking, socializing, running, smoking, …
- Computer helps researcher search data:
  - "find all the moments when the subject might have been cooking"
  - "query the subject whenever the subject is near another subject"
  - "show me video clips of moments when the subject was with other people"
  - "indicate where the subject spent the most time"

Personalized mobile computing device

Take your pick…

Powerful, inexpensive, sensor-enabled mobile computing device *carried nearly everywhere*

The mobile computing device…

- Color touch screen
- Light, comfortable to carry everywhere
- 1GB+ disk space
- Sound player (MP3 and other)
- Sound recorder
- Camera
- Fingerprint recognizer
- 400+ MHz processor
- Always on wireless connection

- Battery life
- Cost (not for long)

- Barcode scanner
- Handwritten input
- Speech input
- Video game player
- GPS / location detection
- Accelerometers
- Biomonitors

New developments in pattern recognition

- Innovation:
  - Real-time recognition of activities (e.g. walking, running, posture, cooking …)
  - Recognition of affect (e.g. frustration, stress, anger)
  - Speech recognition
  - Recognition of socialization activity
- Remaining challenges:
  - Real-time recognition of many activities
  - Unencumbering recognition of many emotional states

Technologist's interest

- Want to design technology for real-world environments and to test technology in context, but…
- Vast majority of homes and workplaces do not look anything like our labs and prototype environments!

Motivation for sensing/measurement tools

- Behavior is "situated", i.e. influenced by environment
- Simulating natural setting in lab difficult (impossible?)
- Real environments are terribly complex
- Need sensors to measure *reaction to interventions* in context of everyday life

Examples

- New developments
- **Examples**
- Emerging opportunities
- Challenges

House_n: tools to study natural settings

Portable data collection and intervention toolkit

PlaceLab residential research facility

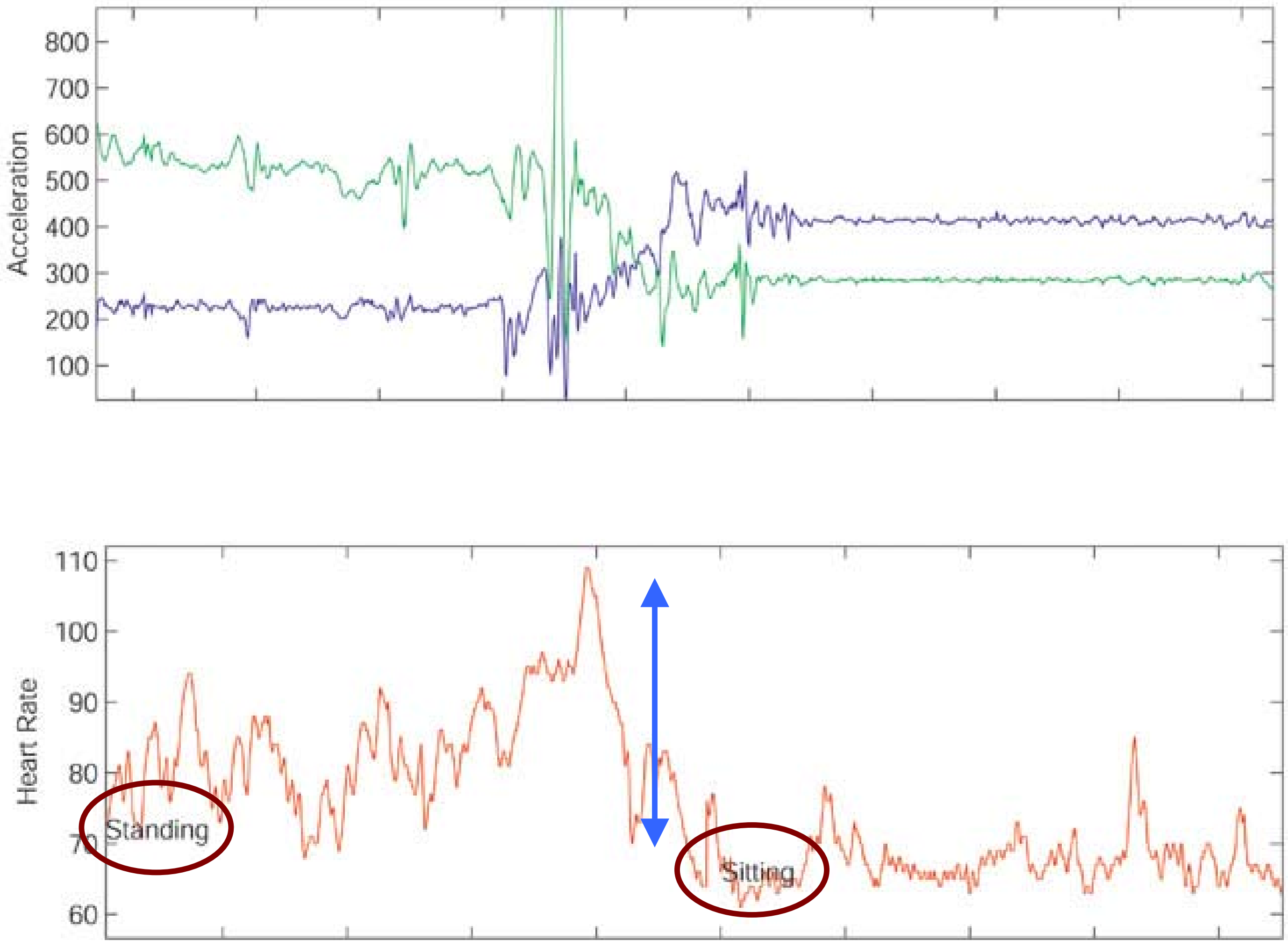
Context-aware experience sampling

Electronic experience sampling

MIT version: new data collection capabilities

E.g.: trigger sample based on position

E.g.: trigger sample based on HR

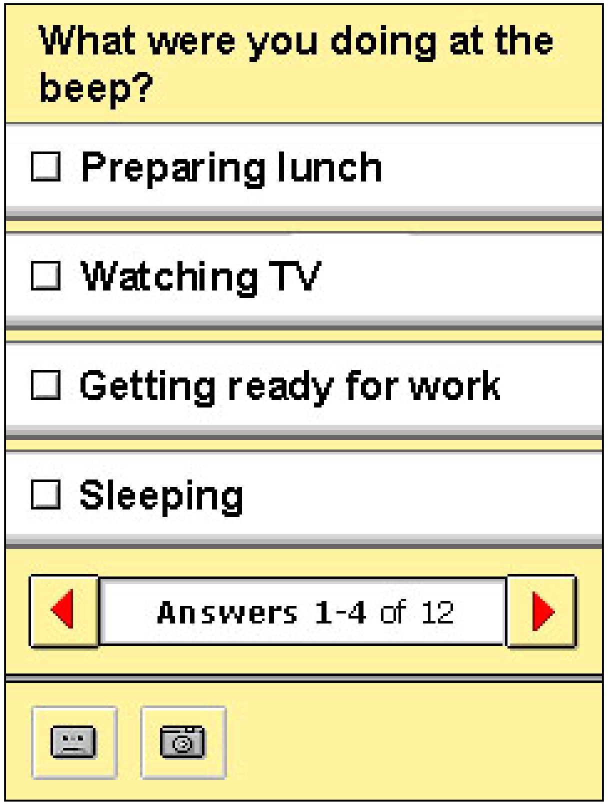


Context-aware experience sampling

- Scheduling options
  - Fixed
  - Random within intervals
  - User-initiated
  - *Triggered by context*
- PDA plug-in sensors and sampling devices
  - GPS
  - Heart rate
  - Bar code scanner
  - Camera
  - Accelerometers
  - Future: Bluetooth

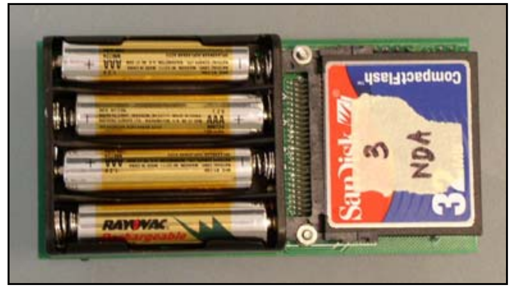
Context-aware experience sampling tool

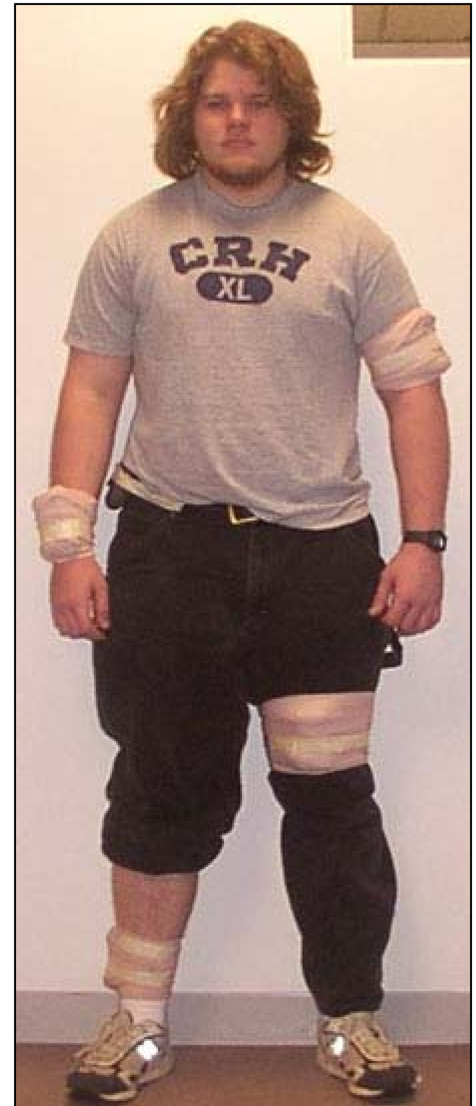
- Uses at MIT:
  - Machine learning algorithm development
  - Physical activity interventions
  - Studying interruptions (using biometric data)
  - Planned: workplace studies
- Available to researchers http://caes.sourceforge.net



Mobile activity recognition

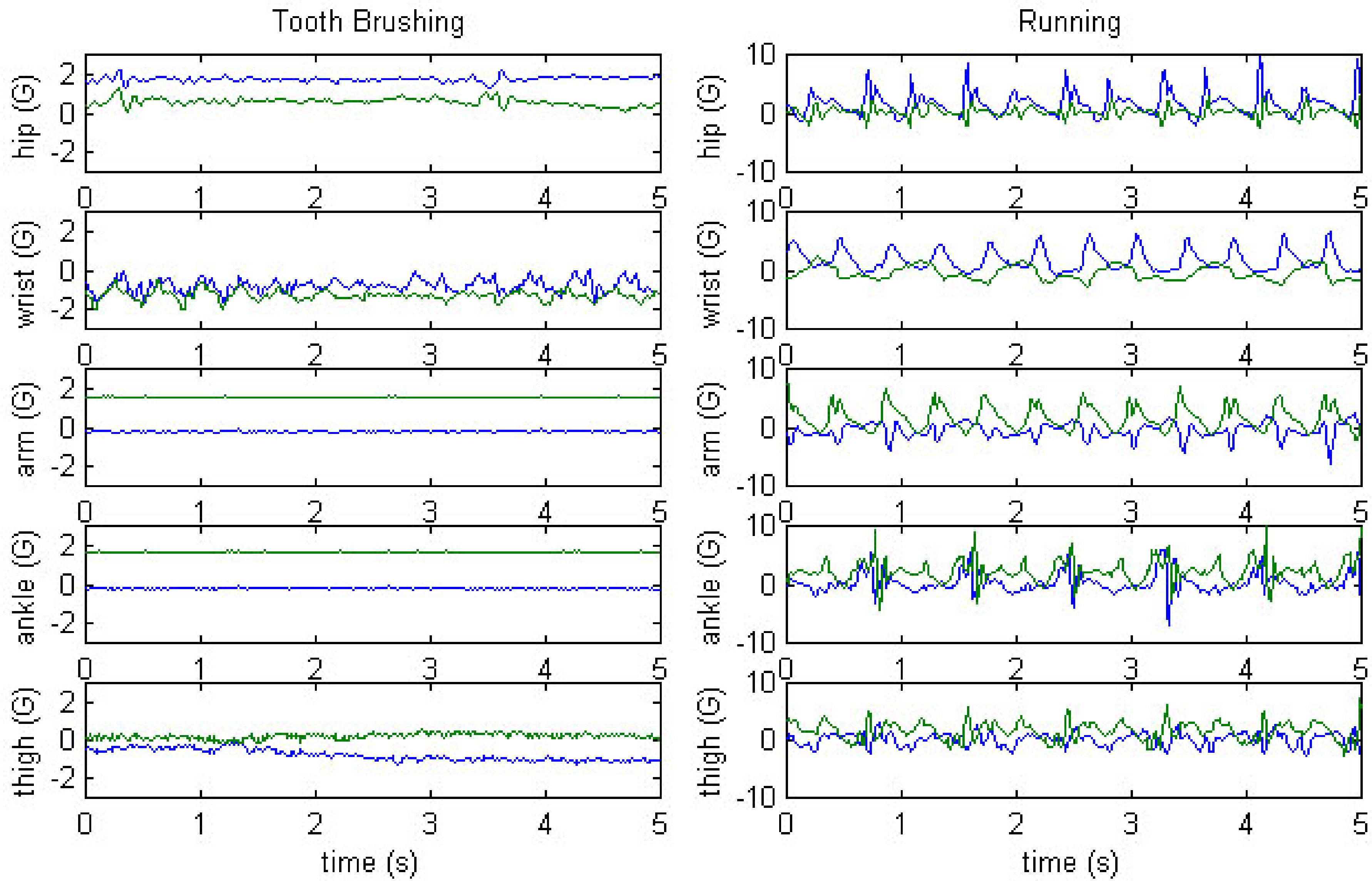
Multiple, wire-free accelerometers





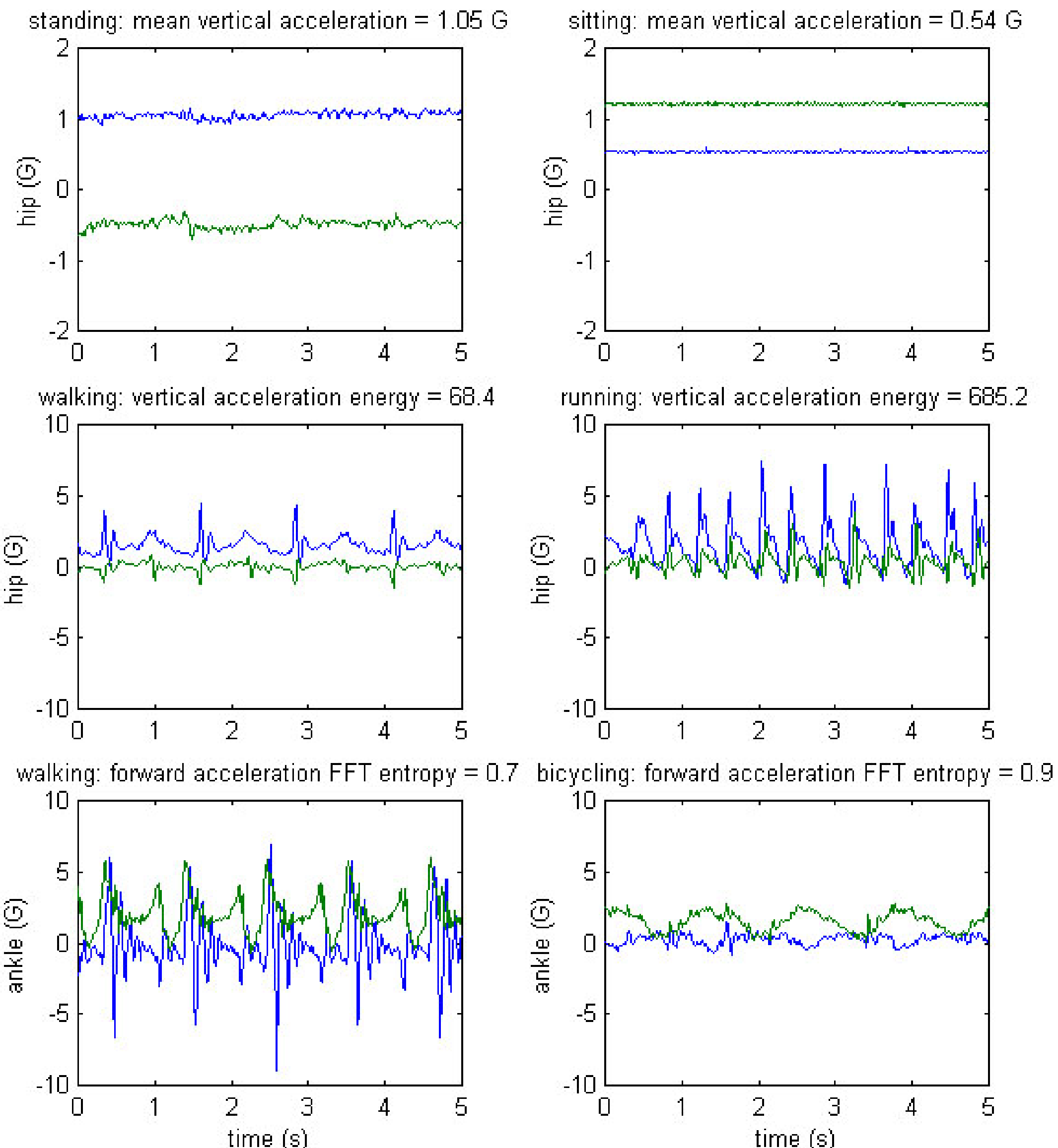
- Placement
  5 points
- Collect data up to 24 hours
- 2 axis, 85Hz sampling
- No wires
- Next version (Fall):
  watch size, comfortable,
  real-time wireless

Mobile activity recognition



Mobile activity recognition

- Features



Mobile activity recognition

- Aggregate confusion matrix for fast C4.5 classifier based on leave-one-subject out validation for 20 subjects using laboratory and obstacle course data.

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	<-- classified as
942	46	0	0	2	0	0	0	8	3	8	1	4	2	7	0	3	8	8	8	a = Walking
83	1183	9	0	3	2	0	0	8	1	3	8	14	1	16	0	8	53	38	11	b = Walking while carrying item
0	9	762	11	0	1	17	3	0	0	0	0	0	0	0	1	0	0	0	0	c = Sitting and relaxing
0	0	10	893	9	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	d = Working on computer
0	0	0	7	774	11	0	0	0	6	1	2	2	0	4	0	2	0	0	0	e = Standing still
0	2	1	0	12	712	9	1	0	0	2	1	10	1	18	0	26	1	4	3	f = Eating or drinking
0	0	43	21	0	1	320	28	0	0	0	0	0	0	0	0	0	0	0	1	g = Watching TV
0	0	23	1	1	6	16	961	9	0	2	0	0	1	0	1	2	0	2	22	h = Reading
14	12	0	0	1	1	0	17	491	10	1	1	1	1	1	0	1	3	4	1	i = Running
0	1	0	0	5	0	0	0	8	830	10	0	1	0	3	0	2	1	0	1	j = Bicycling
9	3	2	16	30	22	45	9	3	35	309	37	26	21	99	1	38	12	3	26	k = Stretching
4	10	0	0	6	5	2	7	0	6	23	500	13	2	9	3	6	5	3	2	l = Strength-training
1	7	0	0	5	10	0	0	0	0	3	9	403	11	10	1	26	1	6	4	m = Scrubbing
1	0	0	0	0	3	1	0	0	2	0	1	9	885	11	0	1	0	2	2	n = Vacuuming
1	1	0	0	1	6	0	0	0	1	4	1	4	7	822	8	4	0	1	3	o = Folding laundry
0	0	4	9	0	2	1	7	0	0	0	0	1	0	10	791	8	0	0	0	p = Lying down and relaxing
1	2	0	0	3	32	0	0	0	1	5	0	18	7	10	9	637	10	2	10	q = Brushing teeth
7	14	0	0	1	1	0	0	0	3	2	1	1	0	2	0	12	351	10	5	r = Climbing stairs
84	70	0	7	20	60	0	0	8	40	33	11	24	34	40	0	0	59	502	160	s = Riding elevator
5	2	0	0	5	6	0	1	0	1	0	3	3	1	0	0	3	7	16	127	t = Riding escalator

Current work

- Development of comfortable, 24 hour wireless, 2-3 axis mobile accelerometers
  - Smaller than CSA actigraph
  - Real-time data streaming
  - High sampling rate
- Real-time mobile activity recognition for context-sensitive data collection

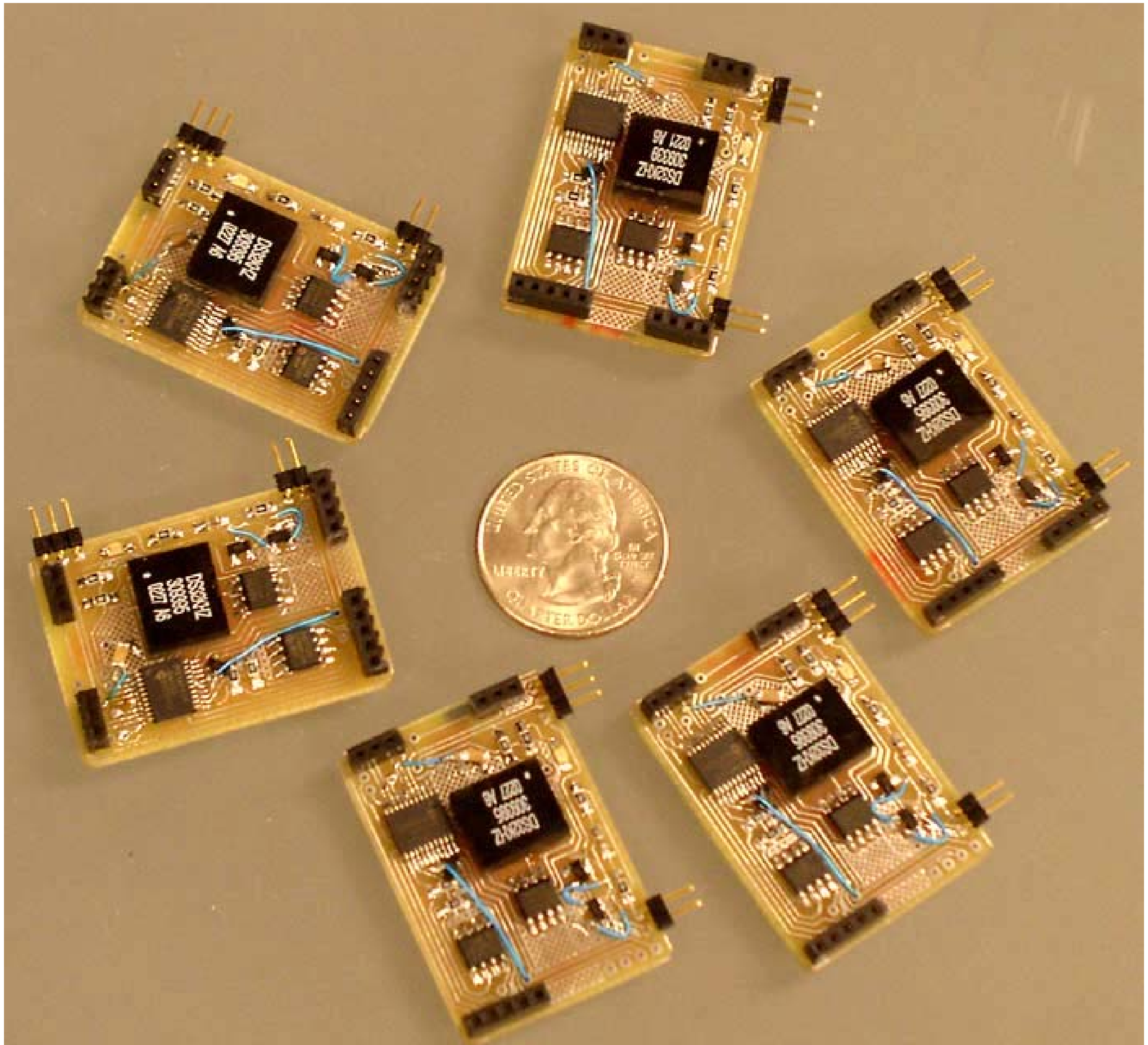
Tape-on environmental sensors

Environmental sensor kit

- Data collection board with swappable sensor
- Small, robust
- Relatively inexpensive ($27 each at qty of 150)
- Collect state change data 4+ weeks
- +/- 2 second timestamp synchronization
- Tape-on install

- Non stigmatizing
- Relatively non-invasive

Environmental sensor kit



One subject's home

- 3 hours with small team
- Install: tape-on
- Approx. 85-100 sensors in small 1 bedroom
- On | Off
- Open | Closed
- Position | Identity

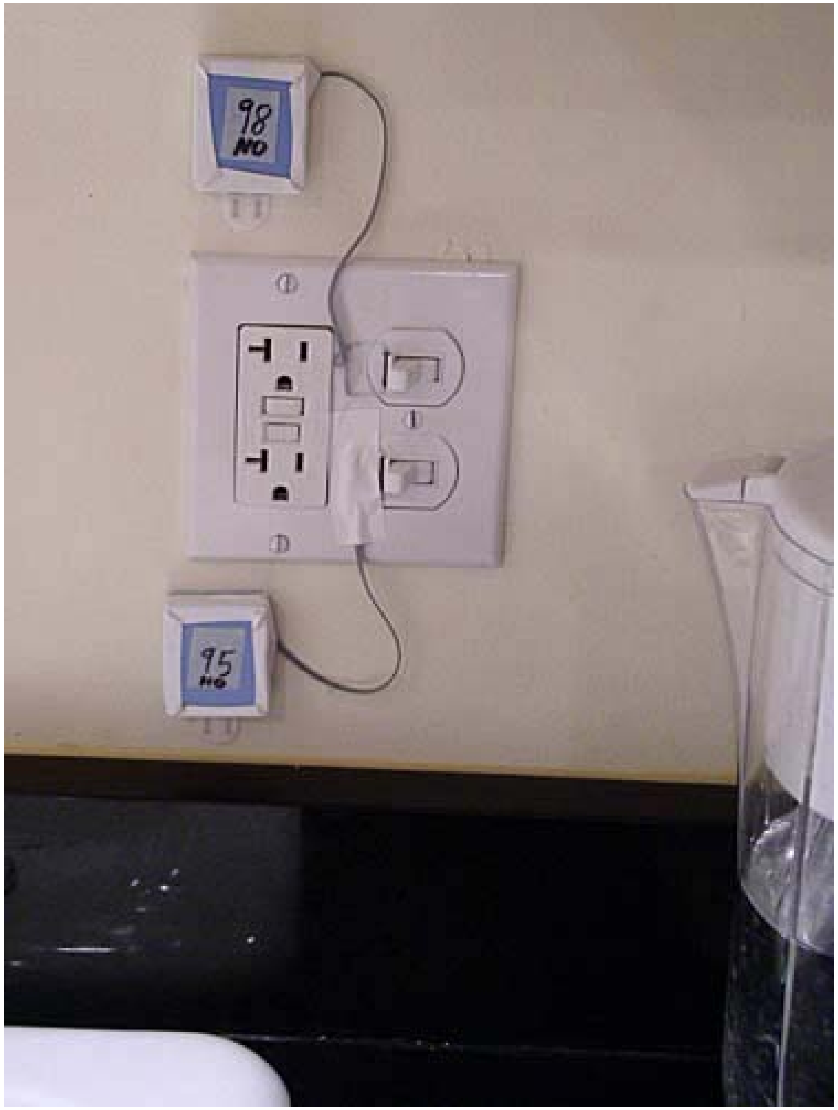
Studying behavior in context


79
NC


69
NC


90

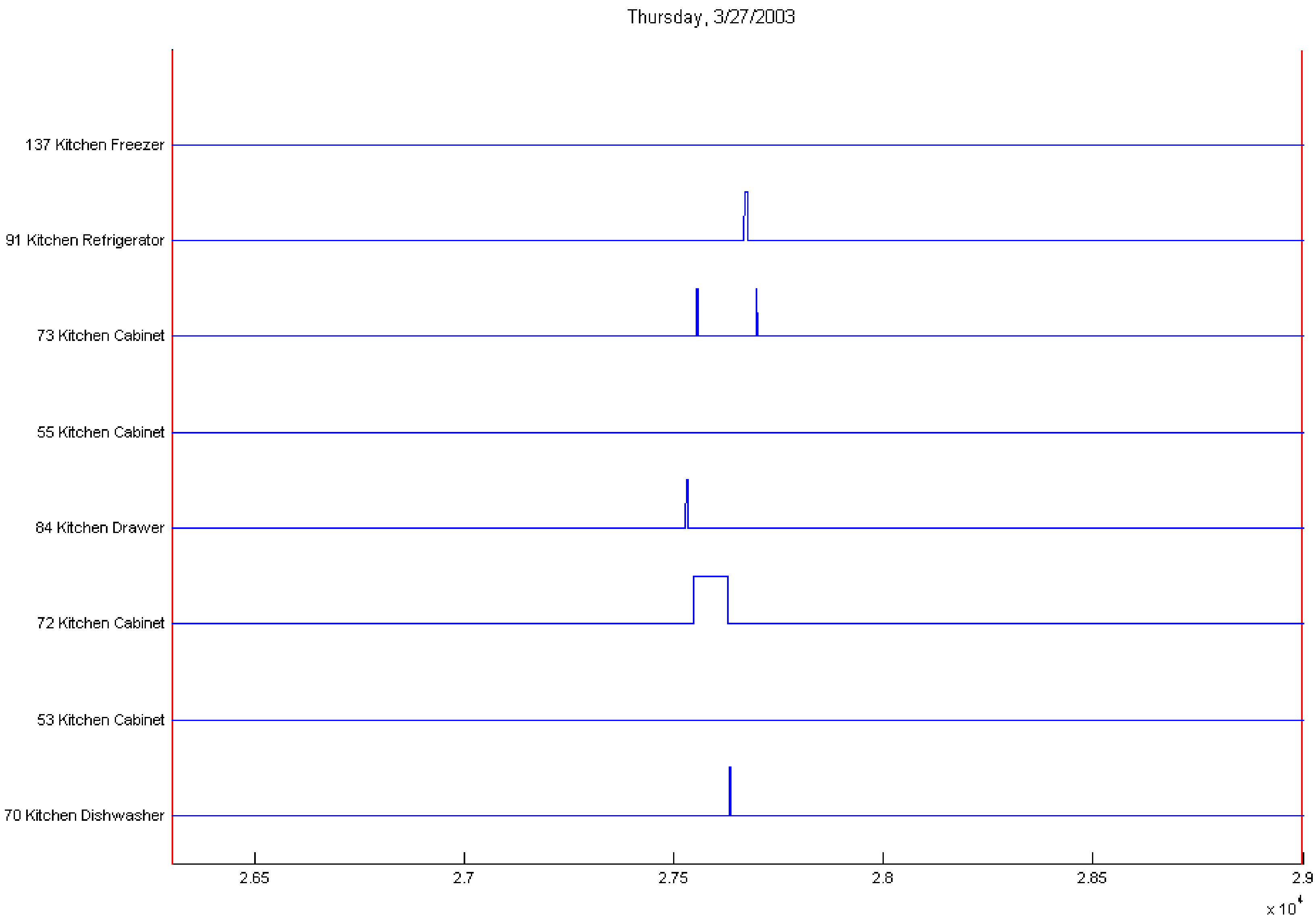

OFF
REAR
OFF
FRONT
LITE
LO
HI
PRECISE
99
hb


98
NO
95
NO

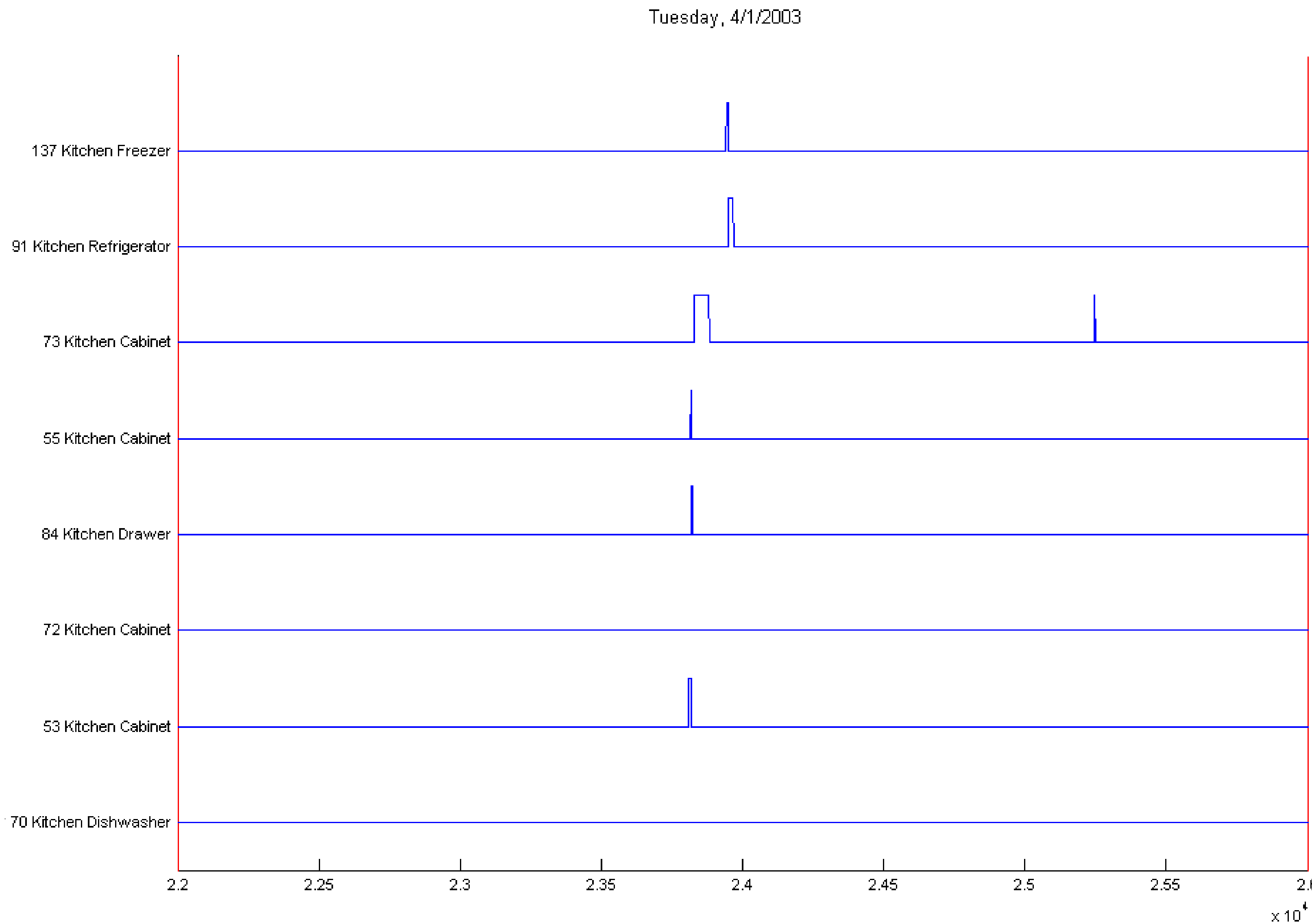

142

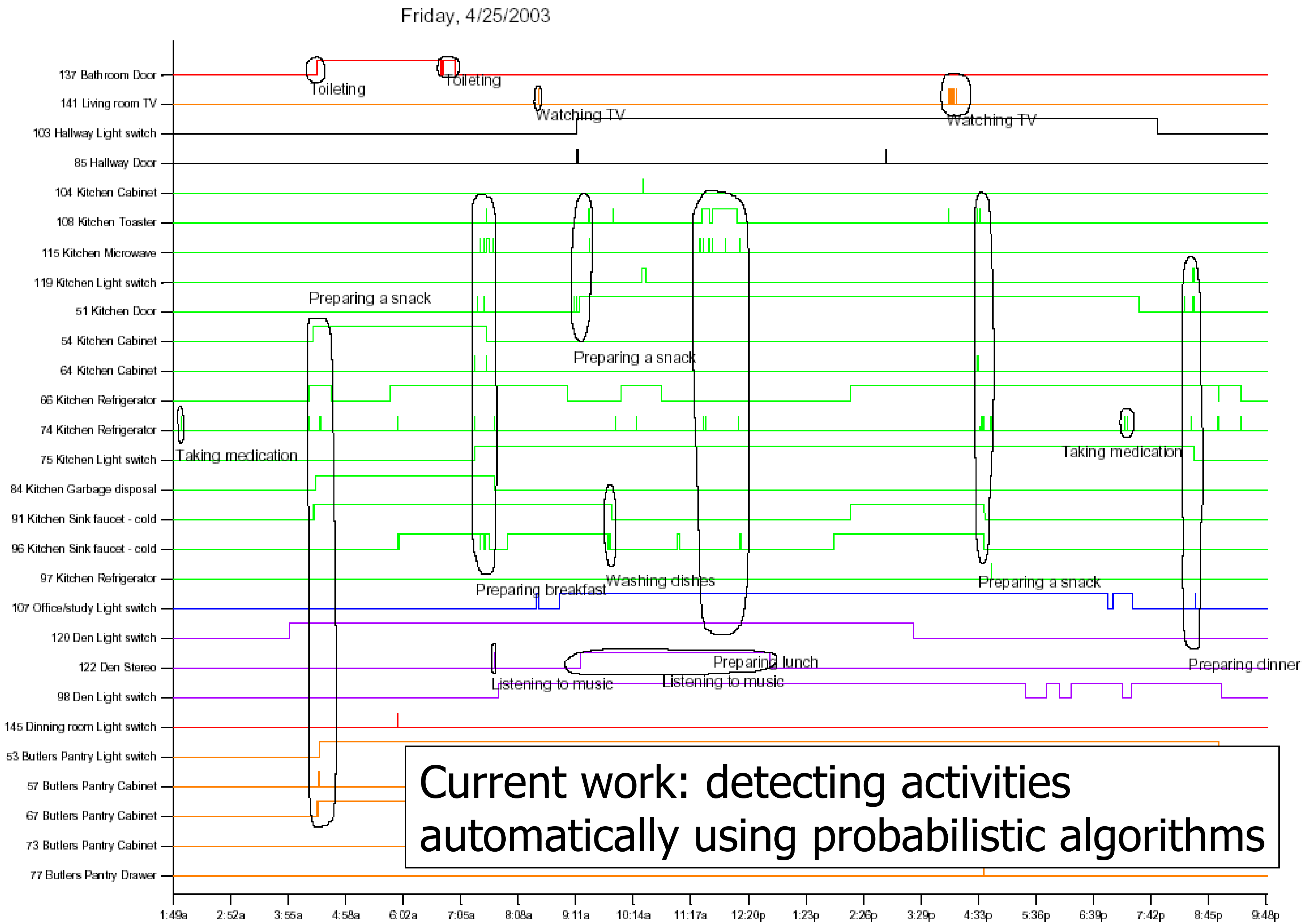

GLAD

Cooking breakfast 3/27



Cooking breakfast 4/01



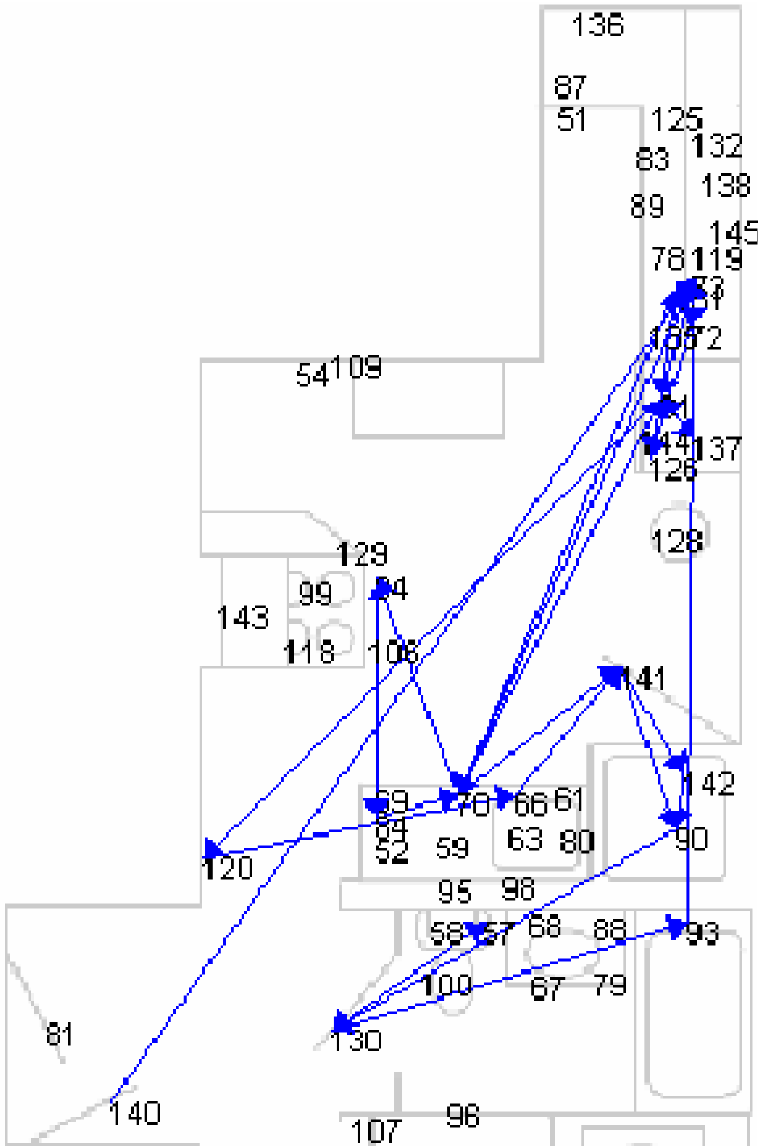


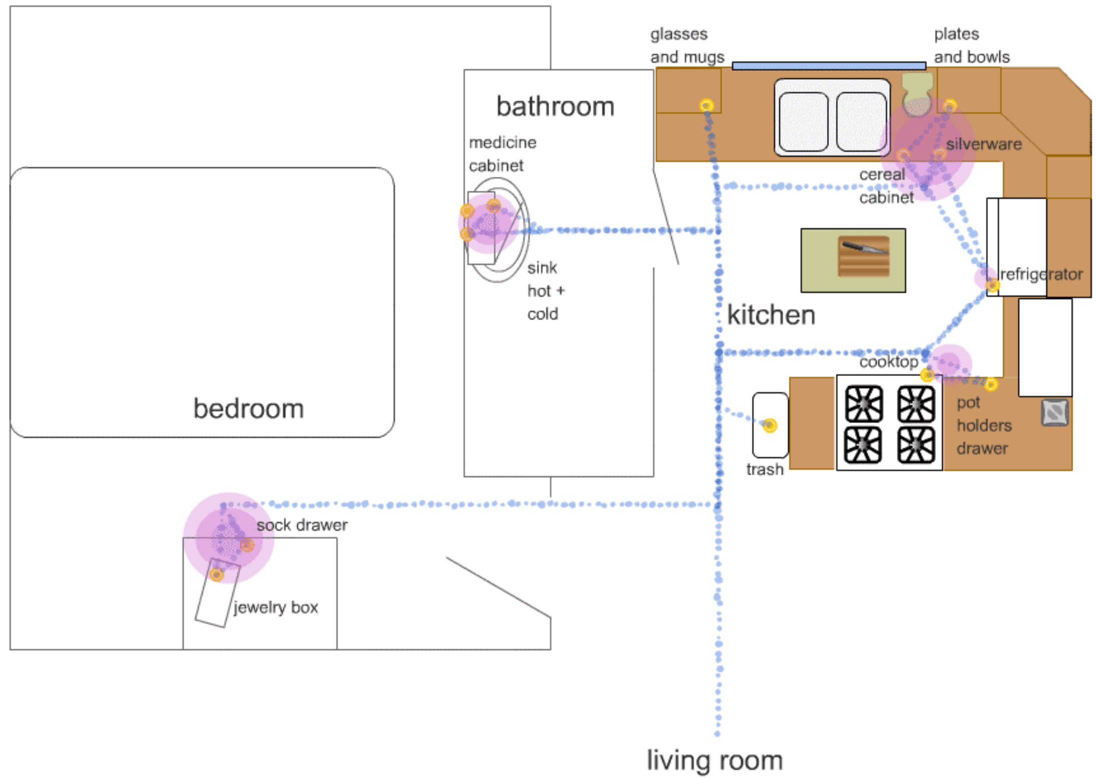
Current work: detecting activities automatically using probabilistic algorithms


FRUIT & FROSTED O's


FRUIT & FROSTED O's

Collaborative development of interventions





The PlaceLab

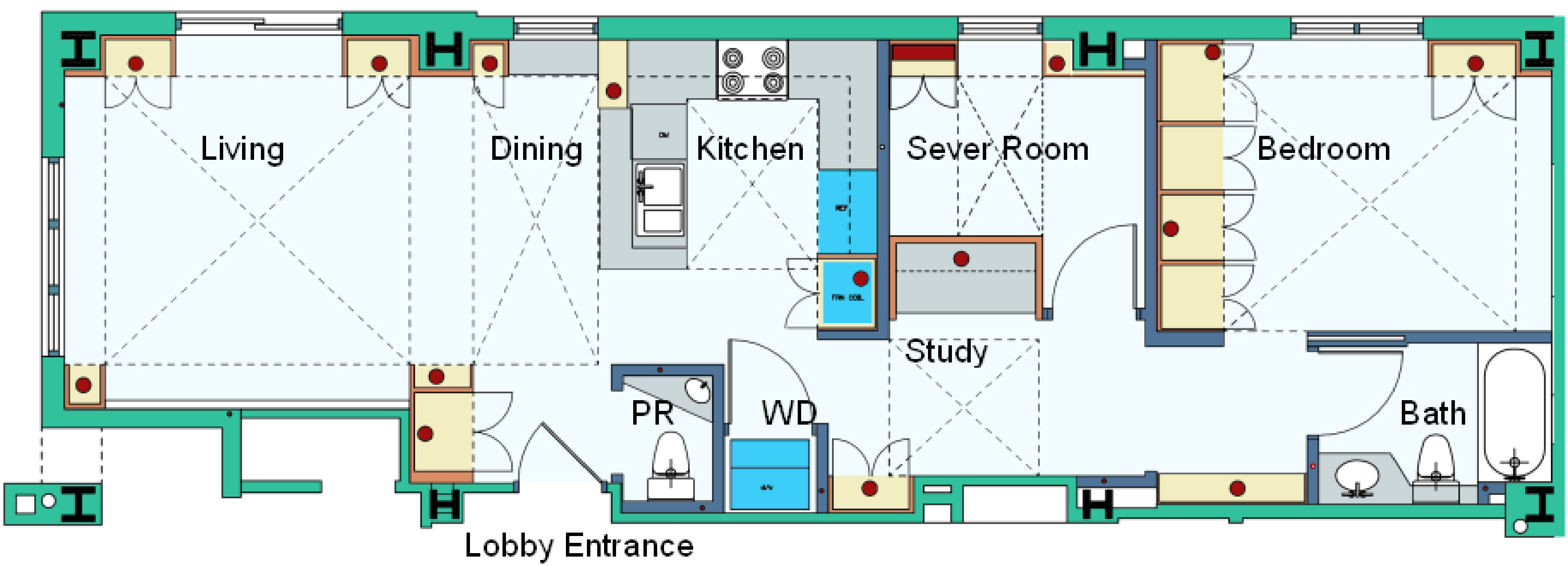
- A residential laboratory for studying behavior in the home

PlaceLab

- **Not** a prototype
- **Not** a demonstration

PlaceLab floor plan / cabinetry

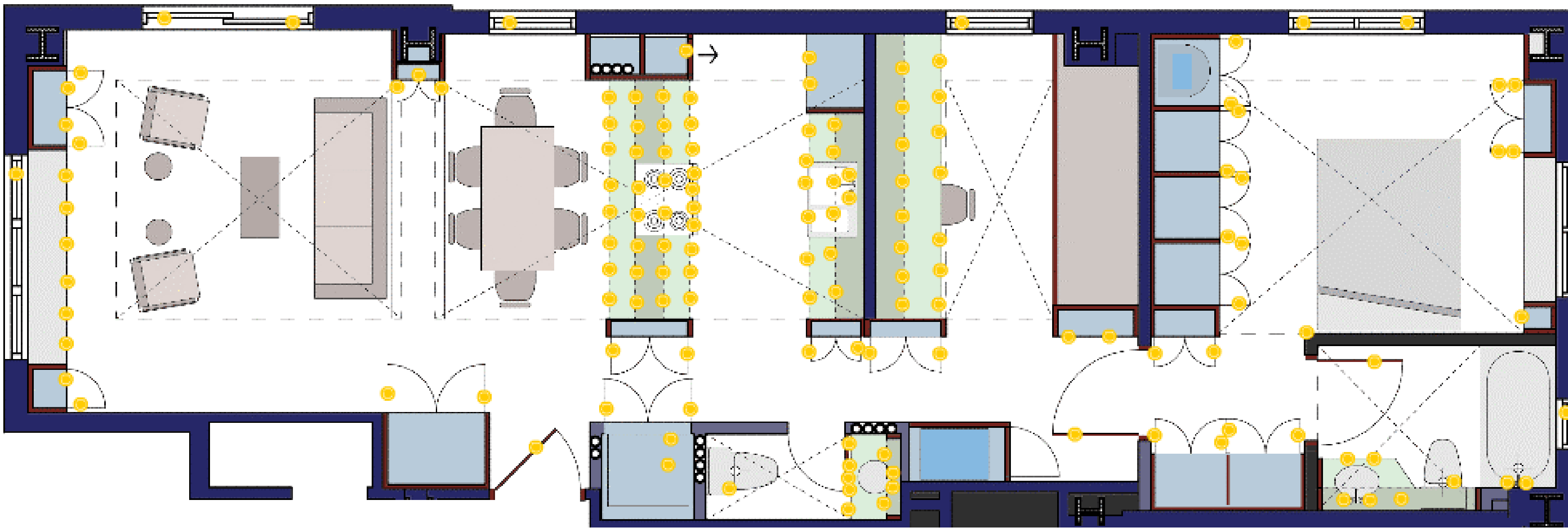
Section Perspective



Floor Plan

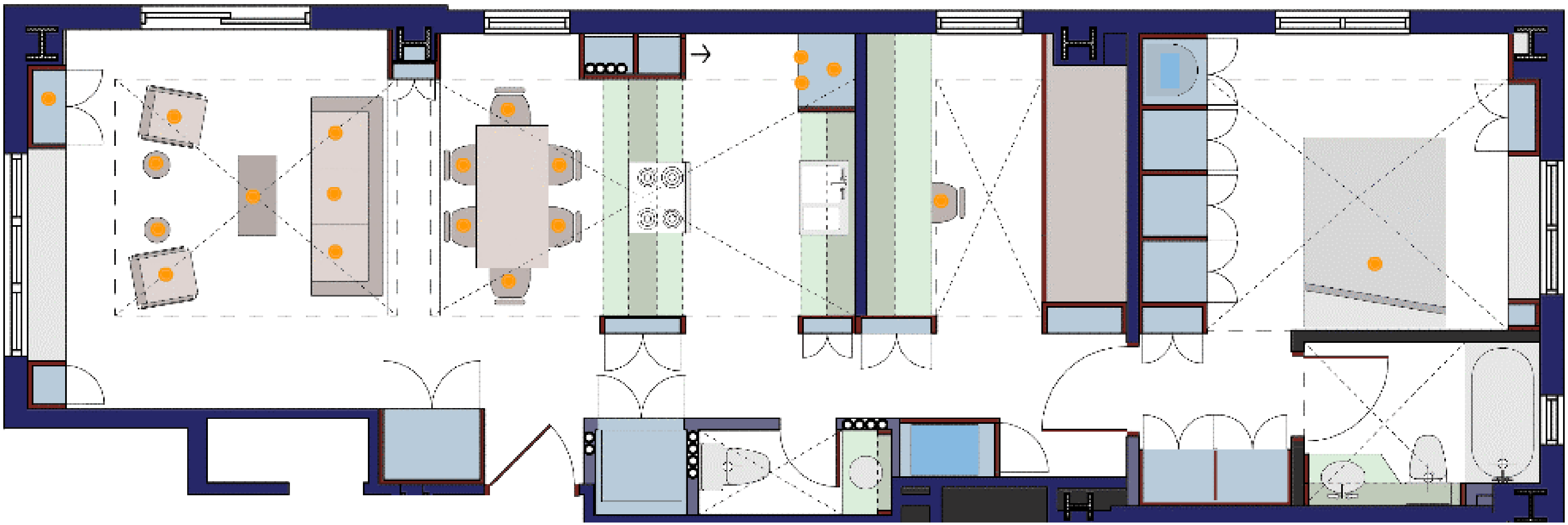
Each infill cabinet

State of fixed things



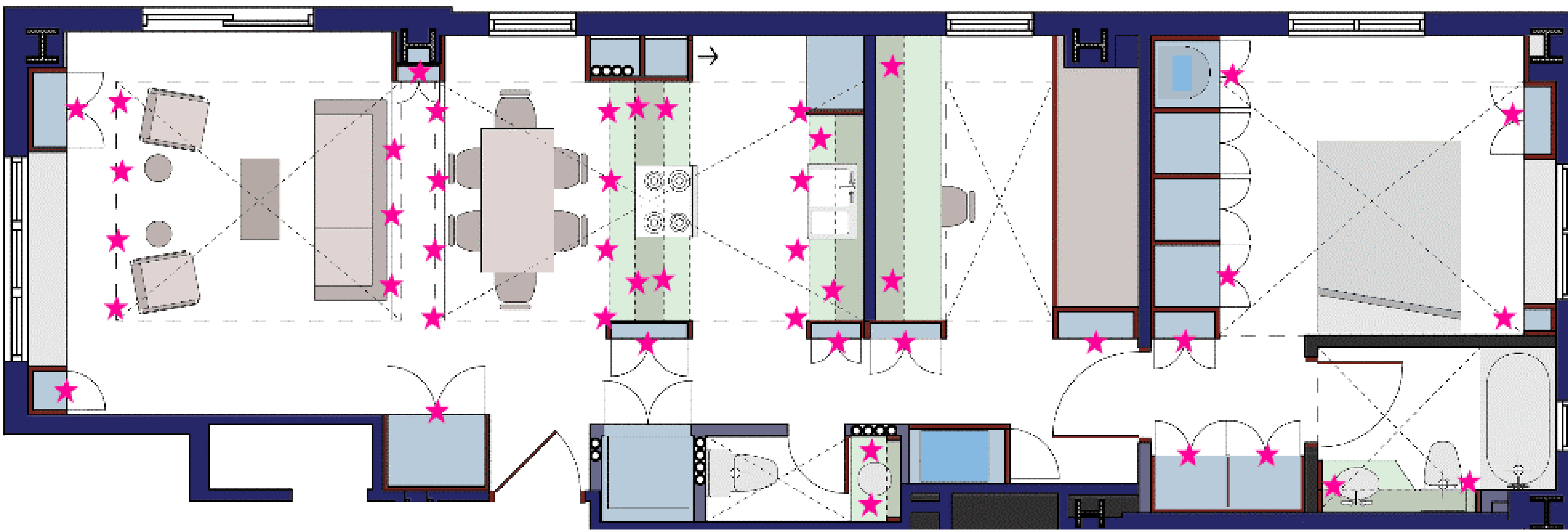
Switch sensors in cabinets and appliances

State of movable things



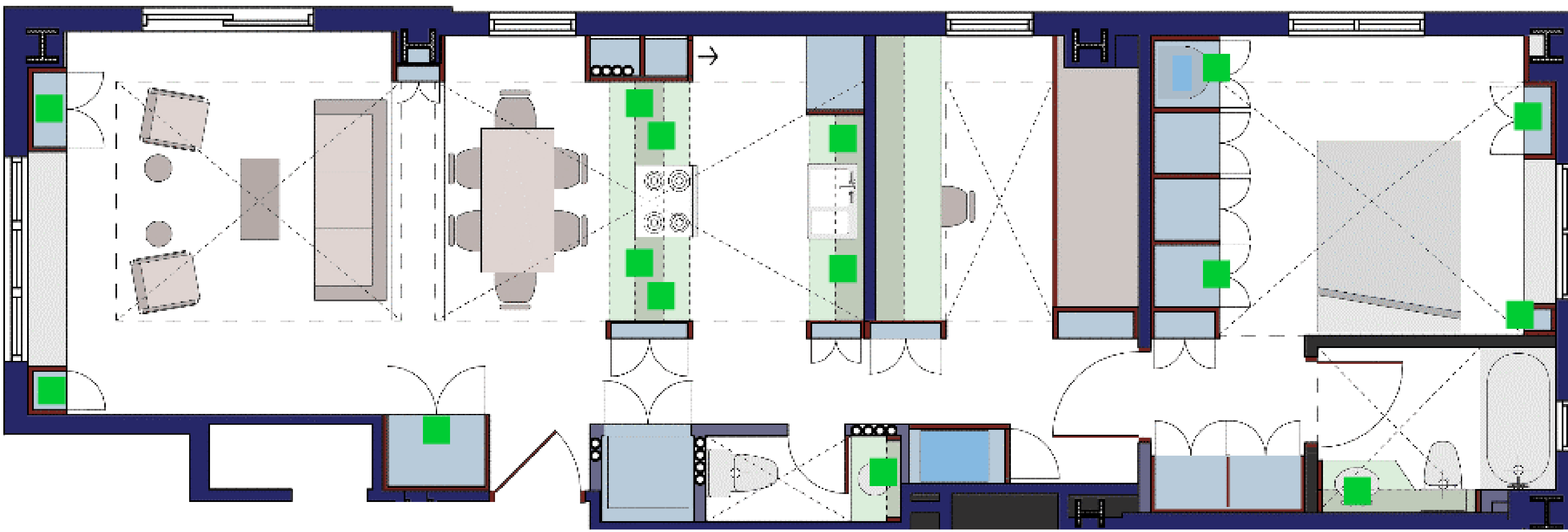
Wireless sensors in movable furniture

Location/identity of people



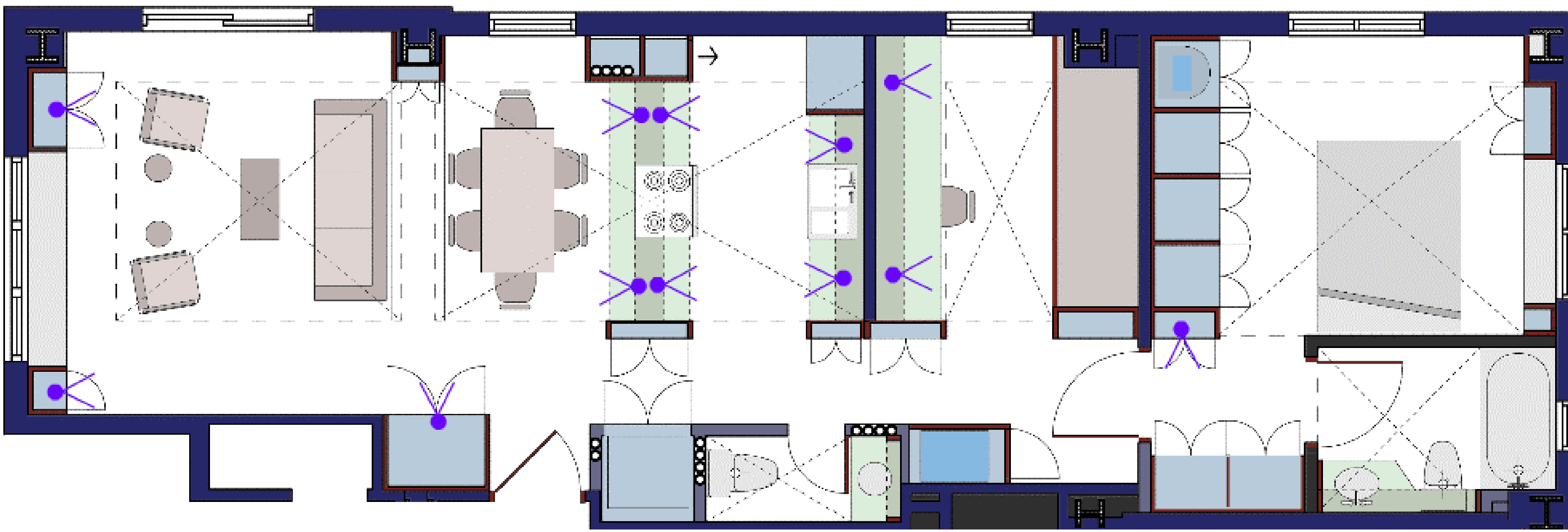
IR transmitters

Environmental conditions



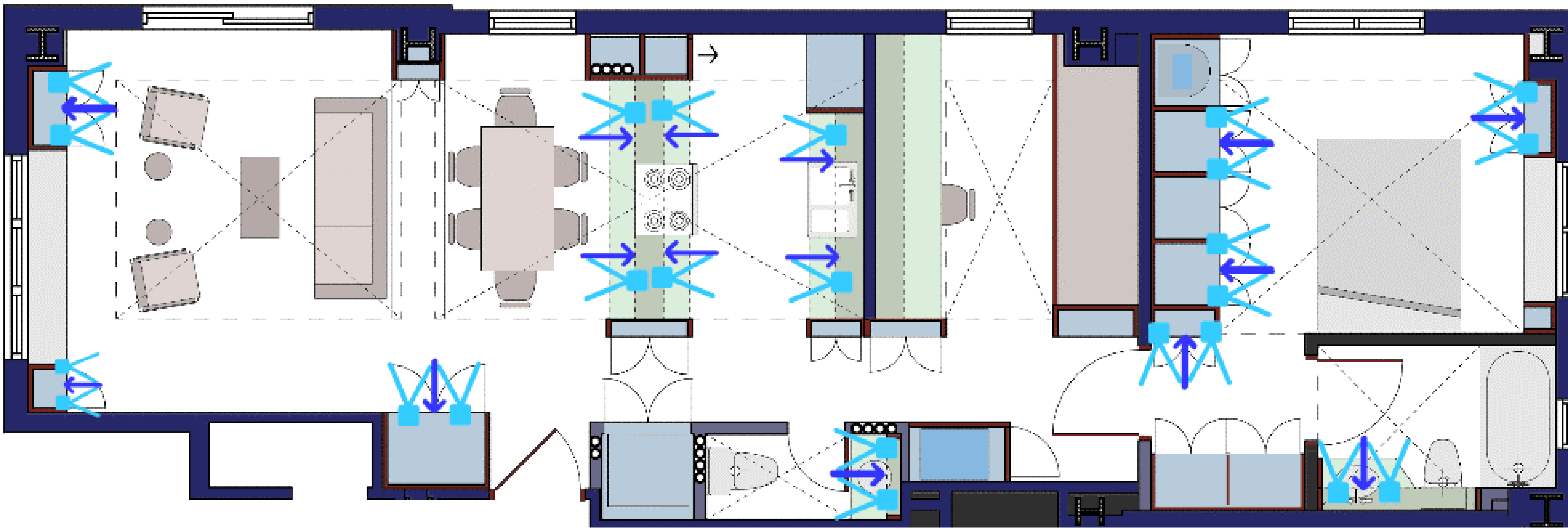
Locations of temperature, humidity, CO, CO2, and smoke sensors

Optical sensors (IR & visible)



IR and visible light sensors

Communication w/ directed audio



Speakers and microphones

PlaceLab: Design for real people

- Heard yesterday: "We are assuming our research subjects are behaving like rats"

- Use measurement tools to study:
  - How to study people in natural settings
  - How to show user's own data to get them to help researchers design new, effective interventions

Emerging opportunities

- New developments
- Examples
- **Emerging opportunities**
- Challenges

Measuring and motivating health behavior

- Switch/bend sensors
  - Doors
  - Cabinets
  - Drawers
  - Thresholds
  - Appliances
  - Objects
- Wearable sensors
  - Accelerometers
  - Heart rate monitor
  - Self report
- Multi-purpose sensors
  - People-locator tags
  - Auditory sensors
  - Optical sensors

new machine learning algorithms

- Activity recognition
  - Eating meals
  - Talking
  - Sleeping patterns
  - Taking medications
  - Cleaning
  - Cooking
  - …

health applications

Detect **change** in activity;
Motivate behavior changes;
Provide info at teachable moment

Best bet: link advice with activity

- Simple messages (points of decision/behavior/consequence)
- Right time ← Requires computational sensing
- Right place ← Requires "pixels where you are"
- Non-disruptive ← Requires attention to UI design

⇩

- Big impact
  - 20% shown for energy
  - Substantial gains for preventive medicine

Challenges

- New developments
- Examples
- Emerging opportunities
- **Challenges**

Volume of data / ethical collection

- Terrabytes possible
- Annotation can be time consuming, costly, and challenging
- Ethical issues may be raised by data collection

Data analysis techniques

- New types of multi-modal data
- Sensor algorithms noisy/probabilistic
- Desired contextual cues can be ill-defined:
  - E.g. "Cooking"
  - E.g. "Jittery"
  - E.g. "Getting dressed"
  - E.g. "Busy"

Thank you!

- For more information:
  - intille@mit.edu
  - http://architecture.mit.edu/house_n
- Looking for preventive health collaborators
- Portable tools available
- PlaceLab opens in October.
  Call for proposals soon.

  (Propose a study on EMA and interruption?)